Branching and growth of plantings in fifth year of a seedling seed orchard of Masson pine (*Pinus massoniana* Lamb.)

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Abstract: The features of branching and growth studied included height, diameter at breast height (DBH), total number of branches, annual height growth, annual branch elongation in the year of elongating, annual branch number for four consecutive years, diameter of branches of different ages, and diameter of stem where branch-whorl originates. For features of total growth and overall branching, no significant differences were found between families, except for DBH. For annual features, no significant differences were found in annual stem height growth, annual branch elongation in the year of elongation and diameter of branches. In the last four years, differences in number of branches were not significant in the first two years but were significant in the last two year; differences in stem diameter where branch-whorls grow were significant for the four consecutive years. Trend of annual growth and branching features of families can be divided into three types as increasing type, stable type and fluctuating type. Most of families have an increasing type with respect of annual height growth and annual branch elongation, while most families belong to a fluctuating type with annual branch number. The results indicated that in the fifth year after planted in seedling seed orchard, differences between families were mostly insignificant. This result may have two main explanations: one is the growth rhyme in early ages of Masson pine, the other one is the complex paternal components to form the open-pollinated families. Family selection seemed to be not useful based on the result. It is suggested to select some of families in the nursery instead of to use all the families when establishing seedling seed orchards with open-pollinated families from plus-trees.

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Introduction

Masson pine (*Pinus massoniana* Lamb.) is planted largely in mountainous areas every year. It is also the most important tree species for pulp and paper industry in China because of its wood's high quality and relative low price. Although more than 1000 hectares of clonal seed orchards have been established around the country, seed yield from clonal seed orchard is not easy enough to need for forestation. Seed-orchard seeds accounted for less than 10 per cent of the seeds for forestation in Fujian Province, which is even lower in other South China provinces where Masson pine plantations are established. The majority of the seeds for forestation are collected from normal stands and some seed-production stands (mother-tree stands, or seed stands (Zobel *et al.* 1984)). Therefore, it is necessary that more seeds should be produced from both clonal orchards and seedling orchards in order to guarantee the genetic quality of the future forests in China.

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Seed orchards of more than 90 tree species, among which 60 species belonged to conifers, have been established around the world (Wang *et al.* 1994). Most of the seed orchards are clonal ones, while the number of seedling seed orchards is relatively smaller. Advantages and disadvantages of these two kinds of seed orchards were discussed world-widely. The way of establishing a seed orchard depends on many factors, including flower periods, productivity, etc. Although it is difficult for Masson pine to reproduce through cuttings, grafting is still a way to solve the problem. Because Masson pine' s seedling plants can begin to produce flowers between the fourth and sixth years while the grafted plants produce flower between the third and fifth years, and also because there have been problems arising from clonal seed orchards (including late grafting incompatibilities, low and unstable seed yield), seedling seed orchards have been established in Fujian. There are three seedling seed orchards of Masson pine established in the winter of 1991 or early spring of 1992.

Information on growth and branching should be important for seed orchard management (Zhang 1996). Branches are main components of crown, and they are also the most important part where cones occur, but information of branching and crown structure seemed to be mostly research areas for non-tree-breeders (e.g. Baldwin *et al.* 1997). Tree breeders did limited work in this area (Lai *et al.* 1998; Jensen *et al.* 1992; Van 1986); most re-

searches carried out by tree breeders concentrated on seed and/or cone yields (Shong *et al.* 1986; HO 1980, 1984; Caron *et al.* 1992; Zhang 1996). Many people tried to increase seed yield from seed orchard by pruning (Van *et al.* 1962; Varnell 1969; Hand, 1979; Hinze 1986; Philipson 1985; Ross *et al.* 1989). Information on the branching and growth of plants in the seed orchards will offer substantial basis for management measures of seed orchard in pruning. In the paper the author presented results on early growth and branching features of plants in a seedling seed orchard of Masson pine established in the winter of 1992. The goal of the research was to learn the early performance in growth and branching features of open-pollinated families so that reasonable ways in family selection can be found based on the results.

Materials and methods

The seedling seed orchards were established with open-pollinated seeds collected from plus-trees in Longyan, Fujian Province. It is located in Shanghang County. Seedlings of 198 families were raised in the nursery and planted in the seed orchard when they were one-year old. The families were randomly laid out in the seed orchard, each family was planted as 20 replications with one tree per plot in a block. The initial spacing distance was 3 m×3 m.

In the early spring of 1998, traits of growth and branching were investigated for 10 families, five individuals included in each family, within Block 4. Fig. 1 shows the typical branch structure of a Masson pine seedling in the fourth year after planted. Usually, the tree stem sprouts once a year, only one whorl of branches grow annually, and the whorled branches also elongate once a year, which makes it easy to judge the annual height growth, and annual branch elongation length and the number of branches growing in the same year. Note that E_2 on the first whorl of branches has little to do with E_2 on the second whorl of branches except that they grow in the same year, and it's the same with E_3 on the first and the third branch whorl. Annual height growth, including H_0, H_1, H_2, H_3, and H_4 were measured. Since heavy natural pruning of Masson pine, the first whorl of branches of the plantings measured did not exist, therefore, in the paper, H_0 was the sum of seedling height planted and the annual height growth in 1993. H_1, H_2, H_3, and H_4 stand for annual height growth from 1994 to 1997, respectively. Diameter of stem where branch whorl grows and the diameter and elongation length of every branch were shown in Fig. 1, that is, E_1 on the first branch whorl, E_2 on the second branch whorl and so on (Fig. 1).

Results and discussion

Overall growth and branching features

Overall growth and branching feature included height, DBH, and total branch number. Results of ANOVA were presented at Table 1. It was shown that differences between families were only significant in DBH. The results indicated that it might be hard to find significant difference in height or total branch numbers even in the near future, provided that there is enough space for growth. The reason is that there has been little severe competition between families for growth within the five years concerned. In other words, all families have been able to grow under relative optimistic conditions. On the other hand, there is not significant difference due to a characteristic of the species.

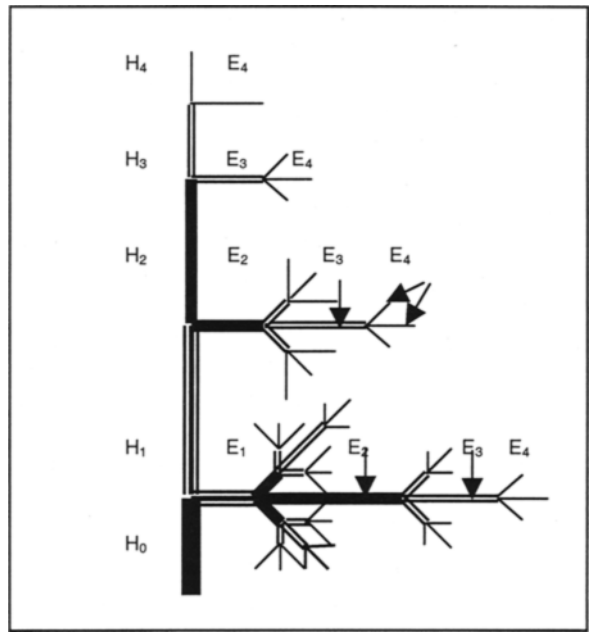

Fig. 1 A typical branch structure of a young plant of Masson pine in the fourth year after planted

Only half of the crown is illustrated: H_0---the height of seedlings when planted; H_1--- the annual height growth within the first year, i.e. the year when seedlings is planted; E_1--- the elongation length of branches within the first year; H_2--- the height growth within the second year; E_2 --- the elongation of branches in the corresponding year, and so on.

Usually, most of young Masson pine plants grow very slowly within the first three years. Maybe the slow growth lasts for another two to three years followed. A third explanation should be due to the complex components of the paternal in stands where plus-trees were selected. If it is the main cause, tree breeder should be more careful when selecting plus-trees for seed collecting. The attention might be paid on growth of tree around the candidate plus-trees. Further more, the insignificant difference may be due to experiment errors in the site where the seed orchard was established, which could make it difficult for tree breeders to make a family selection that is becoming necessary as tree crown grows bigger. Since the environment factor like water and nutrition of nursery is easier to be controlled to be even-distributed, a preliminary selection should be made in the nursery just before planting seedlings in the

field for seed orchard establishment. There were reports of significant differences between progenies of plus-trees on nursery tests (Qin *et al.* 1990; Wang *et al.* 1990). Or we might put an emphasis on within-family selection. No matter how the differences were, insignificant differences did not necessarily mean poorer growth in families in the seedling seed orchard than progenies of unimproved stands. A report on progeny test with the same materials as those used in this seed orchard indicated that more than 50% of the families had better height growth than the control in the sixth year, the percentage was 65.2% for DBH (Qiu 1998).

Table 1. Overall growth and branching features by ANOVA

Trait	*F* value
Height	1.22 ^{NS}
DBH	2.23 *
Total Number of Branches	1.86 ^{NS}

Notes: The sources of variance were divided into between-families and experiment errors. *---significant at 5% level. NS--- not significant at 5% level.

Annual growth and branching trait

For annual height growth, branch number and annual elongate length of branches in Fig. 1, the result showed that the annual height growth was not significantly different between families within each year from 1993 to 1997. It was the same as annual branch elongate length. In order to learn whether there was significant difference between families at H_0, variance analysis was also carried out for H_0. The result showed that there was no significant difference between families for H_0. It was an argument to be careful to make selection in the nursery based on the overall growth analysis.

For annual branch number, there was no significant difference in 1993 and 1994, but the difference became significant at the level of 10% and 1% in 1995 and 1996, respectively. This indicated that differences between families at the trait (Annual branch number) increased as the plants grew older. Since most female flowers and cones are expected to occur on upper branches, the increasing difference in annual branch number may affect the cone and seed yield from different families when the seed orchard comes to its production period.

On the other hand, a combined over-year ANOVA was carried out. The result agreed quite well with the above results based on individual annual analysis (Table 2, 3). There was no significant difference in annual height and annual branch elongation between families, while there was in annual branch number. No significant interaction was found for any of these three traits (annual height, annual branch elongation and annual branch number) between families or years. There were extremely significant differences between years in every one of these three traits. It meant that height growth changed greatly from year to year, to learn the way it changed is to learn about the trend of annual height growth in the consecutive years.

Table 2. Growth and branching features in different years by ANOVA

Year	Annual height growth	Annual branch number	Annual branch elongation
1992~93	0.84^{NS}	--	--
1994	1.36^{NS}	0.62^{NS}	1.40^{NS}
1995	0.46^{NS}	1.08^{NS}	0.72^{NS}
1996	0.77^{NS}	1.97^{NS}	1.70^{NS}
1997	1.33^{NS}	4.20**	0.61^{NS}

Notes: Numbers in the table are *F*-values of ANOVA, height in 92~93 was a sum of seedling height when planted and the annul height growth within the year planted, i.e. in 1993. **--- significant at 1% level. NS--- not significant at 5% level.

Table 3. *F*-values of combined over-year ANOVA of growth and branching features

Source	D.F.	Annual height growth	Annual branch number	Annual branch elongate length
Family[F]	9	1.68^{NS}	1.93*	1.28^{NS}
Year[Y]	3	51.02**	7.31**	59.28**
FXY	27	0.58^{NS}	1.50^{NS}	0.89^{NS}

Notes: NS--- not significant at 5% level; *---significant at 5% level; **---significant at 1% level.

The trend of annual height growth of the families can be divided into three types based on the family average. In Table 4, the first type, Type A, was increasing type, the annual height growth increased steadily from 1994 to 1997. The second type, Type B, was a stable one; there was hardly any change in annual height growth from 1994 to 1997. The third type, Type C, was a fluctuating type; the annual height growth fluctuated without any apparent trend. Those families of increasing type may be very good candidates for a short-rotation forest because if the trend for very good height growth continues at early ages below 20 years in theses families. Obviously, some other families might grow much faster than Type A when those non-type A families come to the age above 15 or 20, but the Type A will still be very good families for forests to be harvested before 15 years old. Therefore, if we measure more families in the same way, we will probably be able to select enough families for short-rotation forestry.

Most of the families belong to increasing type in branch elongation; most of the families belong to fluctuating type in annual branch number. Although the trends were generally called fluctuating type, among them they mostly occur like a wave, i.e. they change from big numbers to small numbers, then change into big numbers again. More plants should be observed for more years, in order to see the trend collide with that of 'good and poor seed yield from seed orchards'.

Table 4. Trend of growth and branch structure of young Masson pine based on average performance of families

Family	Annual height growth /cm				Type	Annual branch number				Type	Annual branch elongate length /cm				Type
	1994	1995	1996	1997		1994	1995	1996	1997		1994	1995	1996	1997	
1	28.8	61.6	71.8	77.6	A	6.4	5.0	7.0	9.0	A	17.6	'37.2	41.5	55.3	A
2	54.8	72.2	81.2	110.8	A	8.8	8.2	8.2	7.8	B	20.5	27.5	49.1	57.2	A
3	36.8	61.4	81.0	101.2	A	7.2	5.6	8.0	6.0	C	23.1	29.5	46.3	65.0	A
4	52.6	62.4	82.8	93.2	A	7.2	7.6	7.6	9.8	C	20.6	37.1	38.8	54.8	A
5	42.6	60.8	91.2	84.8	C	8.6	5.6	7.8	5.0	C	22.4	39.0	53.9	59.0	A
6	36.8	73.8	98.4	97.0	A	7.4	6.6	11.2	7.6	C	26.6	25.9	39.9	65.5	A
7	35.0	61.4	76.2	74.0	A	8.4	4.8	8.2	4.8	C	15.0	28.2	43.7	44.5	A
8	50.8	65.6	82.2	89.0	A	7.4	6.6	8.0	7.0	C	24.6	37.7	54.9	53.0	A
9	43.2	77.8	78.0	72.2	B	6.0	8.0	11.2	8.0	C	15.6	32.4	33.0	51.8	A
10	48.2	78.0	73.6	99.8	A	7.4	6.6	9.0	7.8	C	26.2	35.3	29.8	62.2	C

Notes: A stands for increasing type; B stands for stable type; C stands for fluctuating type.

Other features of crown structure

Diameters of branches and the diameters of stem were also measured. By ANOVA based on these traits in individual year, more precisely speaking, they stand for relevant traits at different height of crown above the ground; difference between families in branch diameter was insignificant while the difference in stem diameter was significant between families in each year. An analysis showed that differences were significant in stem diameter, but not in branch diameter between families. Furthermore, there was no significant interaction between families or years (*F*-values omitted). Significant difference in stem diameter between years indicated that stem taper of young Masson pine is high. The significant difference in stem diameter between families was similar to difference in DBH between families.

Conclusions

The differences between families in the seedling seed orchard established with open-pollinated progenies of plus-trees existed mainly in traits of stem diameter in early ages. No significant differences were found in total height growth or annual height growth. Difference between families in annual branch number changed from insignificant to significant.

The insignificant differences between families might be due to growth rhyme of Masson pine, i.e., its young trees usually grow relatively slow within three to five years after planted. It might be caused by complex paternal components of the progeny. Selection criteria should be focused on both seedling height and diameter. On the other hand more attention should be paid to plus-tree selection for seedling seed orchard establishment.

Significant differences in most of traits studied were found between years or sometimes more precisely-referred to different heights of crown above the ground. Most families' annual height growth appeared to be increasing type; the annual height growth kept increasing from the second to the fifth year after planted. Annual branch number fluctuated among years. Trend of annual height growth might be a clue to selection of early-fast-growing families for a short-rotation forest.

The stem diameter at different height above ground of young Masson pine changed sharply among different years, indicating high stem taper of young Masson pine. Selection for volume would not be efficient for trees of younger than 6-year-old.

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